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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MARBLE

BY

OLIVER BOWLES AND D. M. BANKS

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DEPARTMENT OF COMMERCE - BUREAU OF MINES

MARBLE[1]

By Oliver Bowles[2] and D. M. Banks[3]

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DEFINITION OF MARBLE

In its geologic sense the term "marble" is applied to rocks consisting of crystallized grains of calcite, dolomite, or a mixture of the two. Marble has the same chemical composition as limestone or dolomite, the chief difference being that the component particles of calcium or magnesium carbonates in limestone are granular and noncrystalline. Marble is regarded as a metamorphic rock resulting from the recrystallization of limestone.

In its commercial sense the term "marble" has a much wider application. As susceptibility to polish is one of its chief commercial assets, all calcareous rocks capable of taking a polish are classed as marbles. Furthermore, serpentine rocks, if attractive in appearance and capable of taking a good polish even though they contain little calcium or magnesium carbonates, are classed as marble, as they are commercial substitutes for true marbles.

COMPOSITION OF MARBLE

Aside from serpentine and other extraordinary varieties, marble is made up almost entirely of calcium or magnesium carbonates. A calcite marble may consist of 96 to 99 per cent calcium carbonate. A dolomite marble, if impurities are disregarded, contains approximately 54 per cent calcium carbonate and 46 per cent magnesium carbonate. Those consisting of mixtures of calcite and dolomite may have compositions anywhere between these two extremes.

Varying percentages of impurities are present in practically all marbles. The more common impurities are silica (SiO_2), iron oxides (FeO and F_2O_3), manganese oxide (MnO), alumina (Al_2O_3), and sulphur (S). Organic matter may be present in small quantities; in some marbles it has been converted into graphite. The impurities may be combined to form minerals, such as iron pyrites, mica, clay, talc, or pyroxene. The presence of such impurities gives to colored marble the veins and markings that sometimes adapt it to decorative uses.

ORIGIN AND VARIETIES OF MARBLE

Marbles may be classed in three groups:

(a) The first group, which includes by far the largest proportion of all marbles, comprises those resulting from the recrystallization of limestones. Most of them are highly crystalline and are usually white, though gray, black, or other markings may be present. Most of the Alabama, Georgia, Vermont, Massachusetts, Connecticut, and southeastern New York marbles are of this type. The original rocks were formed in the sea, mainly as accumulations of the calcareous remains of marine organisms which were consolidated to form coherent rocks termed "limestone." Heat and pressure, usually accompanied by extreme deformation of the beds, resulted in the highly crystalline condition which most commercial marbles exhibit. Fossiliferous or subcrystalline marbles have been subjected to less extreme metamorphism, the original fossils in many instances remaining almost intact. They possess sufficiently close texture to take a good polish and at the same time show attractive color effects.

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(b) The second group comprises the onyx marbles. These consist essentially of calcium carbonate but are purely chemical deposits that have not resulted from metamorphism of preexisting limestone beds. Such calcareous chemical deposits are of two types. One, which is regarded as a product of precipitation from hot springs, is termed travertine. Most travertines are porous and are not capable of taking a fine polish. They are classed with limestones rather than with marbles. The other type, the true onyx marble, is usually regarded as a deposit from cold-water solutions in limestone caves. Impurities, such as iron and manganese oxides, may be present in varying amounts in the successive layers of this marble, and thus a beautiful banding may result. This type is commonly known as Mexican onyx, because very fine deposits have been found in Mexico. Many onyx marbles are semitranslucent.

(c) The third type is known as "verd antique." The name is applied to marbles of prevailing green color, consisting chiefly of serpentine, a hydrous magnesium silicate. Verd antique is a highly decorative stone, the green color being interspersed at times with streaks or veins of red and white.

USES OF MARBLE

Marble is used mainly for building and monumental purposes, for interior decoration, and for statuary.

Building and monumental marbles should possess the ability to withstand weathering and to retain their attractive appearance. For exterior use qualities of endurance rank equally in importance with appearance. For such outdoor uses, therefore, marbles should be strong, uniform, close-grained (though not necessarily fine-grained), reasonably nonabsorptive, and free from such impurities as may stain or corrode the surface. While uniformity in color was once desirable, the present tendency is toward blending of mixed colors.

For interior decoration, appearance is the prime factor determining the value of marble. Both pure white and variously colored marbles are used for this purpose. Interior marble is widely used for floors, steps, baseboards, columns, balusters, wall panels, wainscoting, and arches. That used for floors and stair treads should be reasonably resistant to abrasion. Brecciated marbles, which consist of angular fragments cemented together in nature, are widely used for columns and wainscoting. Most marbles of this type are imported, as only a limited amount has been produced in the United States up to the present time. Verd antique is popular for interior work. Onyx marble is also popular for interior decorative use, as it possesses a waxlike appearance and an attractive banding. It also finds wide use for the manufacture of gear-shift balls, lamp and ink-well bases, and gift-shop novelties. Interior marble is also used in various minor ways, such as for table tops, lavatory fittings, and sanitary work generally.

Statuary marble is the most valuable variety quarried. It must be pure white in color, uniform and usually fine-grained in texture, somewhat translucent, and must possess a marked adaptability for carving. Numerous statuary and decorative marbles from American quarries are now on the market, each having its own particular trade name.

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Broken or waste marble is used for terrazzo, stucco, riprap, lime manufacture, and for fluxing and chemical uses.

PHYSICAL PROPERTIES

Hardness

Hardness may be defined as the resistance that the surface of a substance offers to abrasion. A pure calcite marble can be easily scratched with a knife. It has a hardness of 3 in Moh's scale. Window glass according to this scale has a hardness of nearly 6. Marbles are harder than most limestones, for while they may consist of the same mineral - calcite - grains of limestone are usually cemented together less firmly, and hardness of a granular rock is measured by the degree of cohesion between grains rather than by the actual hardness of the mineral. Dolomite marbles range in hardness from $3\frac{1}{2}$ to 4. The presence of impurities, such as flint or silicate minerals, may increase the hardness of a marble very greatly.

Weight

The pore space in most marbles is so small that the actual weight does not differ greatly from the weight calculated from specific gravity. Marbles range in actual weight from 165 to 180 pounds per cubic foot. By knowing the average weight per cubic foot the quarryman may measure a block and calculate its weight with reasonable accuracy. The economic significance of weight is chiefly in connection with the necessary strength of equipment for handling and freight charges for transportation. The weight per cubic foot also provides a means of calculating the weight that base courses of high structures must bear.

Solubility

The solubility of marble deserves careful consideration if its use for exterior purposes is contemplated, because all rocks slowly dissolve or disintegrate when exposed to atmospheric agencies. Usually the rate of solution is extremely slow, but it may be fast enough under certain conditions to impair the value of the rock for building purposes. The rate of solution is variable in different marbles, depending on chemical composition, texture, and porosity. Surface waters which contain certain dissolved gases, such as carbon dioxide, dissolve the carbonates to a limited degree. Near large cities various acids from smoke are taken up by rain and increase its power of solution. If a rock is permeable it usually dissolves more rapidly than if impervious. Calcite dissolves more rapidly than dolomite under the same conditions if the texture of each is similar, but the tendency for dolomite to occur with granular texture often reverses the order of their solubility.

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Color

The color of a marble is one of its most important physical properties. It is governed by the nature of the constituents. Marbles consisting of pure calcite or dolomite are white, whereas green is the prevailing color of verd antique, which consists chiefly of serpentine, though it is sometimes mixed with red. Variations from the white color of a pure marble are owing to admixtures of foreign substances. Such impurities may be uniformly distributed and thus give uniform coloration, or they may be present in bands or streaks, giving clouded or otherwise nonuniform colors. Very beautiful banded effects are obtained by sawing veined marbles in certain directions.

The causes of some colors in marbles are easily determined. Black and grayish shades are attributed to carbonaceous matter which is usually present as fine scales of graphite; red, pink, or reddish-brown shades are mainly due to the presence of manganese oxides or to hematite; yellow-brown, yellow, or cream colors are caused by minute grains of the hydrous oxide of iron, limonite. Other colors, such as the bluish tint found in some beds of white marble, are difficult to explain.

Highly colored marbles are usually those that have been brecciated or fractured, subsequent consolidation being accompanied by infiltration of coloring material from surrounding soil and rocks. They are mostly of foreign origin.

Texture

Grains of calcite and dolomite that make up a marble mass are crystalline and have a definite cleavage showing bright reflecting faces on a broken surface. Usually the cleavages appear about equally prominent in every direction. In some marbles, however, the grains are elongated in one direction by the folding or plication of beds; this forms the rift or grain, which is the direction of easiest splitting in marble.

Most marbles consist of a single mineral. This homogeneity is favorable for resistance to weathering because of the uniform expansion and contraction with temperature changes.

The texture of a marble thus depends on the form, size, uniformity, and arrangement of its grains and on the nature and size of grains of accessory minerals. The form and arrangement of grains may be affected by plication or folding of the beds.

Porosity

Porosity is the volume of pore space expressed as a percentage of the total volume of a rock mass. The pore space of high-grade marbles is usually very small, ranging from 0.0002 to 0.4 per cent. A fine-grained marble may have more pore space than one of coarser texture, but the opposite is more often the case.

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Low porosity in exterior marble is desirable, as pore spaces permit infiltration of water which may dissolve or discolor the stone, or may cause disintegration by freezing. Porous stones also collect soot or soil particles and therefore are not satisfactory when exposed to excessive smoke or dust. Practically all marbles recommended for exterior use have low porosity.

Strength

Compressive strength, transverse strength, and tensional or cohesive strength of marble depend largely upon uniformity of texture, closeness of grain, and amount of interlocking of crystals. Compressive strength is the quality most commonly tested.

Although strength alone is not a sure criterion of durability, knowledge of the capability of any stone to withstand stresses of various kinds is of great value if the material is to be used for purposes involving extraordinary strains. For certain purposes, such as bridge piers, abutments, columns, and base courses of very high monuments, crushing strength demands more than ordinary attention. Practically all commercial grades of sound white marbles are capable of sustaining many times the weight of structures in which they are ordinarily used, though some of the brecciated and veined marbles are too weak to sustain heavy loads with perfect safety.

QUALITIES AFFECTING WORKABILITY AND USE

Texture, Composition, and Hardness

Marbles that are fine-grained and capable of taking a high polish are most desirable for interior use; but many coarse-grained marbles are excellent for building and monumental purposes.

Workability is an important property, as the cost of quarrying and finishing marbles that are difficult to work is relatively high. Workability is governed partly by the hardness of individual grains and partly by the hardness of the mass as a whole. In some marbles the grains or crystals are easily torn apart, while in others that have interlocking crystals disruption is much more difficult. Thus, texture and cohesion have a definite relation to workability. If hard impurities are present, working may be very difficult. Although it may greatly increase the cost of working, hardness is a valuable property if the material is to be exposed to abrasion.

Color or Color Patterns

As marble is usually chosen for its inherent attractiveness, color is an important asset. If the texture or color of marble in a deposit varies, care should be taken to quarry in such manner as will tend to produce material that may be closely classified. Some variations in color, though slight, may detract immensely from the market value. Lenses and bands of bluish material may pass irregularly through the white, thus occasioning excessive waste or necessitating classification in a lower grade.

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Each bed in a deposit exhibits more or less constancy of color, some exhibiting more attractive colors than others. Therefore, desirable uniformity in color can usually be maintained by working each bed separately.

Colors may be permanent or may change after exposure to sunlight or weather. Severity of climate is an important factor in such changes. If changes take place the rock may no longer be of value; therefore, permanence of color is to be desired. The more highly colored marbles are most subject to color changes.

Jointing

Joints are natural cracks or fissures that appear in rock deposits. In some marble quarries, joint systems are clear and definite, in others they may be obscure and seemingly rather irregular. They present a serious problem to the quarryman. The importance of recognizing joint systems and quarrying in accordance with them can scarcely be overestimated.

Joints tend to occur in parallel systems. Two systems frequently occur approximately at right angles to each other, which is most desirable for quarrying. If they are closely spaced the rock will be valueless, while if spaced several feet apart sound blocks of commercial size are obtainable. Both direction and spacing of joints as observed at the surface may persist with remarkable uniformity at depths of 100 feet or more.

Whenever possible, channel cuts should be parallel with or at right angles to joints. In paralleling joints, cuts should also be coincident with them even though they are spaced at irregular intervals. Judicious spacing of cuts may thus tend to produce a large proportion of sound stock. Blocks that are intersected by oblique joints are almost useless.

Unsoundness

The term "unsoundness" refers to all cracks or lines of weakness other than bedding planes that cause marble to break before or during the process of manufacture. Greater losses result from quarrying without regard for unsoundness than from any other cause. Operators may greatly increase the proportion of sound stock quarried by making careful study and detailed diagrams of all visible unsoundness and seeking methods of excavation in accordance with conditions.

Impurities

Iron Sulphides. - Iron sulphides such as pyrite or marcasite which are sometimes present in marble may decompose and form undesirable discolorations. In some marbles, however, sulphides will withstand many years of weathering and show no appreciable change. Crystals large enough to be visible to the naked eye are usually quite stable. Discoloration by weathering of small pyrite crystals in exterior marble may not be detrimental, for such color changes may blend with the normal mellowing and aging of the stone. A fair conception of the probable stability of the sulphides present may be gained by making observations and tests. The most reliable information is obtainable by observing stain effects on

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structures made of a sulphide-bearing marble, or on weathered outcrops of the deposit from which the sulphide-bearing marble was obtained.

Marble containing pyrite may be used to advantage for interior structural or ornamental purposes, as bands and patches of the iron-sulphide minerals produce beautiful effects on polished surfaces. Pyrite crystals are very hard, however, and their presence in a marble may be destructive to tools.

Silica. - The presence of silica usually detracts from the appearance of marble. As a rule, the flinty or cherty mass differs from the marble in color or texture thus constituting a blemish comparable with that produced by a knot in an otherwise uniform stick of timber. Occasionally, however, flinty masses are the basis for distinctive decorative markings that are an asset to the stone. Silica is at least twice as hard as ordinary marble, and consequently when present it greatly retards channeling, drilling, or sawing, and is injurious to tools, especially wire saws. A flint ball may divert a saw to one side or may impede or entirely prevent cutting. Moreover, uniformity of finish under a buffer is difficult to obtain on the surface of a flinty marble on account of its unequal hardness.

Silicated Marbles. - Silicated marbles are those that contain silicates, such as pyroxenes, amphiboles, mica, or chlorite. The silicates are commonly formed by alteration of interbedded impurities. Marbles may therefore contain bands of these minerals, which sometimes remain conformable with the original bedding. In such form they are not serious imperfections and may even facilitate quarrying. However, silicate impurities, especially mica and chlorite, may be scattered throughout the mass as a dark banding, which generally detracts from the market value of the stone, though at times the banding may be adapted to ornamental use.

Dolomite in Marble. - Marble composed of alternating masses of dolomite and calcite is undesirable. When dolomite is present in lenses or bands, unequal weathering will result and produce a nonuniform surface. Differences in texture, color, or susceptibility to polish of the two minerals are also probable. Although pure dolomite, or intimate mixtures of dolomite and calcite, are not to be regarded as inferior types of marble, heterogeneous mixtures in the form of lenses, knots, or bands are undesirable, for the reasons given.

MARBLE PROSPECTING

Development work should not be commenced without reasonable assurance that an available mass of sound and attractive marble is sufficiently uniform in quality and abundant in supply for profitable exploitation. By carefully consulting geologic maps and by a study of outcrops a fairly accurate knowledge of the extent, thickness, attitude, and unsoundness of a marble deposit may be obtained. When the bed is completely buried, these features may be determined from carefully oriented diamond or shot drill cores. Such cores will also give necessary information regarding color, uniformity, and general appearance of the stone as well as the extent of the formation.

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The depth of stripping necessary may be determined at small cost by trenching or by putting down churn-drill holes. The nature of the material that makes up the overburden should be carefully observed.

Most marble deposits can be worked profitably only on a large scale, so that a considerable outlay made to determine whether conditions are favorable is money well expended.

ECONOMIC CONDITIONS

The success of a marble enterprise depends upon several important considerations quite distinct from the quality and extent of a deposit. A prospective marble producer should give careful consideration to market demands, prices, transportation facilities, competitive conditions, availability of labor, wage scale, and other economic questions, for which a reasonably satisfactory answer should be obtained before large sums of money are spent. Many enterprises have failed because these matters have not been fully studied.

QUARRY METHODS AND MACHINES

Stripping

Stripping is the first step in opening up a quarry. For most marble quarries the area to be stripped is not large, but if a heavy overburden is present the use of power shovels may be justified. When the surface of a deposit is fairly level, teams and scrapers may be used to advantage. If the rock surface is uneven, or if the overburden is thin, it may be removed by means of large pans which are loaded by hand and handled with a derrick hoist. A common mistake in the process of stripping is failure to move the soil and waste far enough away from the excavation, or to place it over marble beds that might be worked at a later time. Hydraulic stripping is employed successfully at several marble quarries. An adequate water supply and easy drainage are necessary in order to employ this type of stripping.

Quarry Plan

The chief factors which influence the plan of quarry operation are dip of the beds, depth of overburden, and uniformity of the product in the beds; these factors are intimately related. If the desirable beds are thin and dip at steep angles, shallow quarries must be worked along the outcrop, or underground mining must be employed. However, thick beds dipping at steep angles may be worked in deep open pits, as at Knoxville, Tenn. If the strata are flat and the desirable bed is near the surface, a wide shallow quarry results.

As regards flat-lying uniform beds of great thickness a heavy overburden will tend to promote deep quarrying, whereas a light overburden will encourage the development of wider and shallower pits. If beds are vertical or steeply inclined, a heavy overburden will result in deep quarrying or tunneling, whereas if only light stripping is necessary a greater lateral development in the direction of the strike is possible.

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In many marble regions a certain bed will supply stone of better quality than the beds above or below it. Obviously, it is desirable to develop a quarry in such manner as to obtain a maximum supply of high-grade material.

The quarry plan may be influenced greatly by the quality of the deposit. For example, if the marble is of superior quality commanding a high price, removal of a heavy overburden over an extended area may be fully justified, or underground methods might be employed. For a low-priced marble, neither plan might be economically possible.

Channeling

Wall cuts, and many of the subsequent primary cuts in a quarry are made with channeling machines. The machine operates after the manner of a reciprocating drill which cuts a channel or narrow trench as the machine travels back and forth on a track. Channel cuts are usually 1 to 2 inches wide and 6 to 12 feet deep.

The chief factors to be considered in channeling are dip of the beds, soundness, and rift of the deposit. Where the rock is uniform with no open bedding planes and no decided rift, channeling may be conducted on a level floor, a condition which is most desirable. However, if the beds are inclined it may be necessary in order to maintain uniformity to quarry each bed separately. The removal of right-angle blocks from successive dipping beds results in an uneven or saw-tooth floor, which necessitates construction of an elevated track for the channeling machine. An improved method of quarrying on dipping beds is to place the channeling-machine track on the inclined rock surface in the direction of the dip. The force of gravity which tends to pull the machine downhill is overcome by use of a balance weight.

Cuts should run perpendicular to or, more rarely, parallel with joints and be spaced so as to reduce to a minimum the number of joints in blocks. In many marble deposits one system of joints is pronounced, and cross joints are few in number. Under such conditions it is wise to channel in one direction only, at right angles to the chief system. Advantage may thus be taken of the joints in making cross breaks. Cuts should also be made at right angles to the direction of rift in order to take advantage of the direction of easy splitting in making cross breaks by drilling and wedging.

Wire Sawing

The wire saw is widely used in making primary cuts in European marble quarries but has found very limited use up to the present time in America. Some years ago it proved advantageous for certain types of marble quarrying in Colorado, and has recently met with some degree of success in a marble quarry in Arkansas. It is remarkably successful in slate. The wire saw has definite advantages in allowing a low first cost, low operating expense, and usually a reduction in waste. If a faster rate of cutting can be developed, its wider use is to be expected in American marble quarries.

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Drilling

A certain amount of channeling is regarded as necessary in most marble quarries. Separation of rock masses by drilling and wedging should, however, be followed wherever possible, because this method is ordinarily much less expensive than channeling. Drilling and wedging is almost invariably used for floor cuts.

Drilling may be done with various types of equipment. Tripod piston drills are not as widely used as in former years, being displaced by hammer drills which are more quickly moved and easily handled. In some quarries tripod piston drills are used for the deeper holes and hammer drills for the smaller holes of moderate depth. Power is supplied almost exclusively by compressed air, though steam is also used.

Drilling should follow the direction of the rift or grain of marble, for by thus taking advantage of the ease of splitting in this direction the holes may be placed much further apart than when breaks are made across the grain.

The spacing of holes varies from 4 inches to 2 feet, depending on the ease of splitting. They should be as small as possible without detracting from wedging efficiency; most hammer-drill holes are $1\frac{1}{2}$ to $1\frac{5}{4}$ inches in diameter at the top.

Wedging

Wherever possible, blocks should be separated by wedging, particularly where breaks are made parallel with the rift. To obtain a straight and uniform fracture, proper wedges should be used and carefully driven. "Plug-and-feather" wedges are universally employed. The "feathers" consist of two half-round iron bars that fit into the drill hole, and the "plug" is a steel wedge which is driven between them.

A type of wedge that has proved highly successful is one of which the feathers are 3 feet long and the plug 3 feet 9 inches, the additional 9 inches being required for driving. The feathers are curved on one surface to fit the drill hole, and the flat surface is perfectly straight and gives a uniform taper from one end to the other. The important feature is that with the wedge in any position the total diameter of feathers and wedge is the same at all points. As a consequence, when the plug and feathers are inserted into the drill hole, the inner side of each feather is on contact with the plug, and the outer side with the wall of the drill hole throughout its entire length. Therefore when the plug is driven, the feathers are forced apart a uniform distance at every point. As a result the pressure exerted is uniformly distributed over their full length. Straight and even fractures result and are obtained with much lighter sledging than by any other method yet devised.

In driving wedges it is important that equal strain should be on all of them. Wedging should never be unduly hastened, especially in marble that has no rift. A more uniform break will result by giving the rock time to fracture gradually.

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Hoisting

When a block is separated from the bed the next step is to hoist it from the quarry. Blocks should be entirely free before a hoist cable is attached, for interlocking irregularities on a fractured surface may require a strain of dangerous magnitude on the hoisting equipment before the block will move.

A hoist cable may be attached to blocks by grabhooks, by a chain, or by cable slings. Slings are quickly handled, are safe and convenient, and for these reasons are preferred by many. Steam, compressed-air, or electric hoists may be used. Blocks should be hoisted from the quarry and loaded on cars at a single operation if possible; if a second step is necessary they should be placed in a convenient position for future loading.

Sawing

Some quarry operators sell their marble in block form, and no sawing is required; others manufacture it into finished forms, much of it being sawed into thin slabs. For this purpose gang saws are widely used. A gang saw consists of a parallel series of soft steel blades attached to a frame at distances corresponding with the desired thickness of slabs. Clean sharp sand is the abrasive generally used, though some millmen use crushed steel or fine steel shot. Slabs are usually sawed parallel with the grain, though sometimes distinctive markings are obtained by sawing across the grain. Unsound blocks can sometimes be sawed to better advantage into cubic stock than into thin slabs. Wire saws are used to some extent in marble yards, chiefly for trimming blocks.

Coping

Coping is a name given to the edge trimming of marble slabs. Much coping is done by hand, but carborundum machines are also used for this purpose and for cutting slabs into baseboards and tile.

Rubbing

Slabs and blocks cut to approximate size are squared and finished on a "rubbing bed" consisting of a horizontal circular bed of cast iron revolving at moderate speed. Most beds are driven from above by means of a countershaft and gears, though some are geared underneath. The marble is placed in any desired position on the surface of the revolving disk, and when sand and water are supplied to the bed, the slabs are worn down to desired dimensions and smoothness. Carborundum beds are used to some extent for rubbing small pieces. For curved and irregular surfaces hand-rubbing is necessary.

Gritting

Gritting is a process which gives a smoother surface than rubbing. Emery powder is sometimes used as abrasive for this purpose. More frequently abrasive bricks are attached to revolving heads which travel over the surface. The bricks

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consist of silicon carbide or aluminum oxide and are of varying degrees of fineness depending upon the finish desired. Gritting produces what is known to the trade as a "hone" finish. For hand-gritting of curved or irregular surfaces, natural hone or pumice is used, though artificial abrasives are rapidly displacing them.

Buffing

Buffing is the process which gives the final polish to a marble surface. The marble is placed beneath a buffer which consists of a revolving head of felt or other material of soft texture and which is guided over the rock surface as it rotates.

"Putty powder," consisting of tin oxide or a mixture of tin oxide and oxalic acid, is the abrasive used in polishing. Irregular surfaces must be polished by hand, using putty powder on a felt buffer.

Planers

Planers are used for cutting moldings and cornices. Usually the cutting tool is stationary except for the lateral or vertical movements necessary for adjustment. The marble slab is carried on a travelling bed beneath the tool which scrapes it to the desired thickness and to a shape which is governed by the contour of the tool. Of late years a great deal of this work is done with carborundum machines.

Carborundum Machines

Carborundum machines are capable of varied adaptations and can successfully cut curved work, moldings, cornices, and balusters. The wheel of the machine is cut in the shape of a negative of the desired pattern. The marble block travels on the machine bed beneath the wheel which cuts it to the desired shape; or it may be placed on a ball-bearing plate and held against the revolving wheel. In cutting balusters the marble and carborundum wheel are brought into contact while rotating in opposite directions. In fluting or in making balusters it is advantageous to rough out the marble to the general shape desired before working it with the wheel.

Lathes

A lathe must be employed for column cutting. The marble is generally roughed out by hand to within one-half inch of the finished diameter before being placed in the lathe. The work of turning is done by free-revolving cutters which automatically travel along the side of the rough column, cutting into and removing the surplus material as the column revolves. A cutting tool similar to that used in ordinary machine lathes for turning metal shafts is sometimes employed.

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DISTRIBUTION OF MARBLE IN THE UNITED STATES

The important marble belts of the United States are found in the Appalachian region of the Eastern States and in the Rocky Mountain and Coast Ranges of the West. Deposits also occur in several of the Central States and in Alaska. In 1928 the principal States in order of production were: Vermont, Tennessee, Missouri, Georgia, Alabama, New York, and Massachusetts. These States together produced more than 95 per cent of the total for the year.

Tables showing production in tons and value by States, together with other statistical information, appear in an annual report on stone which is published by the U. S. Bureau of Mines. This report may be obtained from the Superintendent of Documents, Washington, D. C. for 10 cents.

PRODUCTION STATISTICS

The following table gives the amount and value of various types of marble sold as dimension stone in the United States during the years 1919 to 1928.

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Marble sold by producers in the United States, 1919-1928, by uses

Year	Building Stone				Monumental stone		Total	
	Exterior		Interior					
	Cubic feet	Value	Cubic feet	Value	Cubic feet	Value	Cubic feet	Value
1919	293,556	$ 653,789	706,388	$2,231,186	1,101,573	$4,899,056	2,101,517	$7,784,031
1920	248,510	864,557	916,390	3,705,534	1,170,100	5,945,510	2,335,000	10,515,601
1921	323,673	1,099,876	1,148,549	4,096,231	815,278	3,099,829	2,287,500	8,295,936
1922	663,500	2,121,893	1,300,260	4,800,490	889,180	3,137,778	2,852,940	10,060,161
1923	909,900	2,448,368	1,518,780	6,012,925	1,152,750	3,731,773	3,581,430	12,193,066
1924	852,940	2,621,088	1,753,240	6,178,131	1,230,450	3,858,190	3,836,630	12,657,409
1925	1,145,690	3,559,686	1,719,610	6,040,425	1,176,090	3,598,907	4,041,390	13,199,018
1926	1,123,990	3,350,434	1,743,950	6,069,505	1,095,220	4,047,857	3,963,160	13,467,796
1927	850,470	2,826,079	1,973,320	7,913,149	1,127,480	4,097,249	3,951,270	14,836,477
1928	1,019,490	3,146,202	2,005,150	8,963,125	1,031,050	3,749,269	4,055,690	15,858,596

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MARKETING

The marble trade is chiefly in the hands of five groups of selling agencies, some of whom quarry or manufacture as well as sell. The functions of these groups are defined as follows:

(1) The so-called wholesalers who sell marble, as a rule, only to the trade in the form of blocks or sawed stock; (2) manufacturers who own no quarries, buy their marble in the rough (blocks or sawed stock), and finish it; in the interior-marble trade, the greater part of the marble finished by manufacturers is also set in place by them; (3) marble dealers or contractors who have neither quarries nor plants, but buy finished marble and sell it to customers, set in place; (4) producers who have quarries but no plants and sell their blocks to wholesalers or manufacturers; (5) manufacturing producers who have both quarries and plants, and who engage in any and all activities of the trade as a whole.

Large manufacturing plants are situated in every active producing region, but the market for practically every marble used in the United States is the whole country. The merchandising of unfinished marble within the trade has no set rules or established general customs. A wholesaler sometimes sells rough blocks directly to owners of buildings in which the marble is to be used, and the owners have the material sawed and finished.

Marble in the block and in sawed slabs more than 2 inches thick is sold by the cubic foot; slabs 2 inches and less in thickness are sold by the square foot. Blocks to be "merchantable" must usually be at least 5 or 6 feet long, 3 feet or more in width, and 2 feet or more in thickness. A standard-sized block in some localities is 7 by 5 by 4 feet, but great variations in size may occur. Measurements should be as nearly as possible what they would be if all irregularities of surface and shape were eliminated.

Contracts for finished marble in place are usually on a lump-sum basis. Much of the marble production is sold on large contracts which are closed long before delivery is wanted.

Marble is classified as to kinds or varieties, and each kind often exhibits enough variation to require separation into two or more grades. Marbles which are both rare and beautiful bring a high price but have a limited market. Those which are agreeable in tone, texture, and finish, and readily obtainable in large quantities bring a fair price and have a wide market. Prices of the more widely used imported marbles practically fix prices for corresponding kinds and grades of domestic marbles.

An operator should thoroughly understand the grades and varieties of his stock in order to be able to convey to the architect a correct idea of what sort of job he can furnish. He must create a market for his own material.

IMPORTS AND EXPORTS

The following table gives imports of marbles for consumption in the United States during recent years:

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Marble, breccia, and onyx imported for consumption in the United States, 1919-1928, by kinds

Year	In blocks		Slabs or paving tile		All other manufactures	Mosaic cubes	
	Cubic feet	Value	Superficial feet	Value	Value	Value	Total value
1919	211,994	$ 602,947	104,102	$25,841	$48,675	$ 4,862	$ 682,325
1920	475,342	1,295,954	53,213	31,106	86,728	18,284	1,432,072
1921	1/ 389,741	815,070	122,940	48,165	113,263	31,446	1,007,944
1922	548,576	1,149,623	296,568	85,087	201,660	25,924	1,462,294
1923	699,546	1,513,582	129,244	54,618	283,109	21,647	1,872,956
1924	654,706	1,279,351	309,999	97,935	205,353	13,158	1,595,797
1925	642,226	1,327,439	671,561	210,072	257,382	15,265	1,810,158
1926	864,895	1,789,570	403,458	222,230	438,712	7,028	2,457,540
1927	959,241	2,526,582	925,792	306,696	561,990	9,218	3,404,486
1928	586,069	1,673,363	845,464	310,785	483,071	6,126	2,473,345

1 Quantity of sawed marble not given.

Exports of marble were not reported separately until 1922. The following table gives exports from the United States since that time:

Marble exported from the United States, 1922 - 1928

Year	In blocks (rough or dressed)	Value
	Cubic feet	
1922	86,144	$292,737
1923	50,466	197,372
1924	47,532	214,047
1925	53,849	249,073
1926	66,293	251,917
1927	65,380	237,233
1928	64,326	254,266

FOREIGN MARBLES IN BRIEF

The principal countries from which marble was imported in order of value during 1928 were: Italy, France, Belgium, Germany, and Mexico. Imported marbles are used chiefly for interior decoration.

At least 80 per cent of the imports are from Italy and consist chiefly of white marble from the Carrara district. Imports from other countries are chiefly various types of colored marbles, and the present tendency in imports is toward a larger proportion of the colored types. Red marbles from France, Spain, and Italy

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are imported into this country in considerable quantity. Monotone marbles, such as the Botticino from Italy and the Hauteville from France, are quite popular. Most of the marble obtained from Belgium is black. This is regarded as the standard black marble. The principal marbles imported from Germany are dark gray and white mottled and blotched with red. From Mexico has come almost the entire commercial supply of onyx marble or so-called Mexican onyx.

RATES OF DUTY

The Tariff Act of 1930 relating to marble reads as follows:

"(a) Marble, breccia, and onyx, in block, rough or squared only, 65 cents per cubic foot; marble, breccia, and onyx, sawed or dressed, over two inches in thickness, $1 per cubic foot.

"(b) Slabs and paving tiles of marble, breccia, or onyx: Containing not less than four superficial inches, if not more than one inch in thickness, 8 cents per superficial foot; if more than one inch and not more than one and one-half inches in thickness, 10 cents per superficial foot; if more than one and one-half inches and not more than two inches in thickness, 13 cents per superficial foot; in addition thereto on all the foregoing, if rubbed in whole or in part, 3 cents per superficial foot, or if polished in whole or in part (whether or not rubbed), 6 cents per superficial foot.

"(c) Mosaic cubes of marble, breccia, or onyx, not exceeding two cubic inches in size, if loose, one-fourth of 1 cent per pound and 20 per centum ad valorem; if attached to paper or other material, 5 cents per superficial foot and 35 per centum ad valorem.

"(d) Marble, breccia, and onyx, wholly or partly manufactured into monuments, benches, vases, and other articles, and articles of which these substances or any of them is the component material of chief value, not specially provided for, 50 per centum ad valorem."

The duties are essentially the same as those given in the Tariff Act of 1922.

PRICES

Marbles vary greatly in quality and therefore in price. The price range may run from $1.50 to $7, or even more, per cubic foot. American marbles for exterior building purposes average about $2 per cubic foot in rough blocks. Prices of interior rough blocks at the quarry are quite variable ranging from $2 to $7, averaging about $3.50 per cubic foot. Monumental stock in rough block averages about $2 to $3 per cubic foot, though not much domestic marble is sold in this form. Second quality Italian marble was selling in New York in 1929 at $5.25 to $5.75 per cubic foot, and French marble at $3. Belgian black marble has sold in New York at about $1.75 per cubic foot in rough block form, though recently the price has been much higher.

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